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S A S K A T C H E W A N

D E P A R T M E N T O F N A T U R A L R E S O U R C E S

A BRIEF OUTLINE OF THE GEOLOGICAL HISTORY OF

NORTHERN SASKATCHEWAN

A N D

SOME PROSPECTING CONSIDERATION

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OF
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The general geological relationships of the rocks underlying the Province of Saskatchewan are already well established through the work of the Geological Survey of Canada, but much work must yet be done to solve many points bearing on problems of economic importance. As has been previously pointed out the rocks of the northern part of the Province are a group of ancient igneous and highly altered sediments formed before the close of the Precambrian eras, while the southern part of the Province is underlain by younger relatively unaltered sediments of various ages and kinds. The Precambrian rock surface is in the thickly settled southern part of the Province buried beneath many thousands of feet of shales, sandstones and limestones that comprise these younger rocks.

The following very generalized table gives the succession of rock types met with in the northern area and indicates their age relation to one another and to the rocks underlying the southern tract. It clearly indicates the great antiquity of the Precambrian rocks found at the surface in the northern section of the Province.

The most recent interval of the geological time scale and the formations formed in it are at the top, and the oldest at the bottom of the table.

CENOZOIC ERA	Quaternary Period	Recent Epoc	Peat, and deposits by present rivers.
		Pleistocene Epoc	Glacial drift and lake clays, a few tens of feet thick.
	Tertiary Period	Clays, sands and sandstones, a few tens of feet thick, found in the extreme south of the Province, e.g., Estevan and Willowbunch areas.	
MESOZOIC ERA	Mostly shales with some sandstones, many hundreds of feet thick, found at the surface or below Pleistocene deposits over most of the southern part of the Province.		
PALAEZOIC ERA	Limestones and shales, many hundreds of feet thick, outcropping just south of the northern Precambrian rocks and known from borings to underly the younger rocks to the south.		
PRECAMBRIAN ERAS	Sandstones and conglomerates (Athabasca Series), many hundreds of feet thick. Granites and related intrusive rock types. Altered volcanics, sediments, schists and gneisses. many thousands of feet thick.		

Precambrian Eras

The Precambrian rocks underly nearly half the surface of the Province and are confined to the area north of the previously described boundary. Although much is still to be done to unravel the intricate history of the rocks of this age exposed in the Province, enough is already known of their character and history to make it certain that they closely resemble the ones found throughout the rest of the vast Precambrian terrain of northern and eastern Canada.

The oldest known rocks in the Province are rocks which were formed on the surface of the earth, and comprise great assemblages of volcanic flows (extrusive igneous rocks), ash rocks (tuffs) and sediments of various kinds derived from the wearing down of previous land masses. Most of the latter type and some of the others were deposited in bodies of water and bedding is often recognizable. Remnants of these volcanics and sediments are known to aggregate many thousands of feet in thickness, in places many miles. Subsequently and possibly also during their deposition these rocks suffered profound and long continued mountain building forces and they were folded into great ranges and chains of mountains. During the time these processes were active the slow invasion of granitic and other plutonic (intrusive) material from deep within the earth's crust took place. Some of this liquid rock material actively 'stoped' or engulfed fragments of the overlying rocks; much more of it advanced in a slower but equally effective manner by slowly replacing, by molecular processes, the original cover rocks, till merely ghost-like vestiges of the former material is in places left. Due to the powerful factors of pressures, heat and replacement the volcanic and sedimentary rocks suffered change. Those surface rocks more deeply infolded or closer to the hot invading material suffered the greatest metamorphism. Volcanics and sediments changed to easily cleavable schists, which are found in many localities, and over still larger areas this alteration proceeded much further and granites and syenites light in colour and uniform in composition but having a definite fine banded structure are present. This gneissic structure is due to the alignment of the present constituent minerals, corresponding in many cases to the structures present in the formerly existing schists which have been replaced. This progressive change due to these processes of metamorphism can be clearly seen in various sections of the Amisk (Beaver) lake area, the northwest side of Lac la Ronge and elsewhere. In these localities the central profoundly altered volcanics or sediments give place towards the margins to schists and these in turn to granite and syenite gneisses.

Intrusive rock types, related to granites and syenites, both light and dark in colour, veins and metal sulphide deposits, further products of this deep seated igneous action also invaded the previously formed rocks. These are found widely scattered through the above mentioned rock terrains and in some cases are of economic interest.

Following these long periods of deposition, mountain building and igneous action, slow processes of weathering and erosion working for vast ages wore this mountainous country to a featureless plain. It had no greater variations in local relief than is now present in the northern part of the Province. The very roots of these mountains were then exposed and are now visible in the gigantic curving sweeps of gneisses and shred-like remnants of schists and other altered rocks. In places the pattern of the roots of these ancient ranges have influenced the location and configuration of the numerous lakes and water courses of the northern region. During this tremendous period of denudation literally miles in thickness of the rocks in this part of the Province were carried away and transported into the seas of this time. One of these seas possibly occupied a north-south basin in the vicinity of the Rocky Mountains of today. None of the resultant sediments are now known to outcrop in the Province. The interval of time represented by this period of erosion is the greatest known in the recorded sequence of events found in Saskatchewan, and represents a duration of time probably

equivalent to that represented by much of the time involved in depositing the thousands of feet in thickness of post-Precambrian sedimentary rocks underlying the southern part of the Province. Unfortunately, in common with the rest of the Precambrian areas of Canada, during this period great areas rich in metaliferous deposits were undoubtedly destroyed and carried away. Merely remnants of this mineral wealth is now left.

The next recorded geological event in the Province is the deposition of a series of, what are still flat lying, late Precambrian sandstones and related rocks on the flat surface previously described. This unfossiliferous group of rocks known as the Athabasca series is at present believed to be older than the oldest fossiliferous Palaezoic rocks found south of the Precambrian boundary, but are nevertheless friable, nearly in the attitude in which they were deposited, have suffered no mountain building movements and in character resemble closely much younger rocks. A remnant of these sediments occupies, within the Province, an oval-shaped area 250 miles long east and west and about 150 miles wide north and south. This area is bounded on part of its north border by Athabasca lake, on the east it is inferred to extend to the west shore of Wollaston lake, the south boundary crosses the south part of Cree lake and westward it is known to extend into Alberta. A few dark gabbroidal dykes of plutonic material are known to cut these rocks, but no light coloured granitic rocks, or rocks to which many metal mineral deposits are related are known to intrude this series.

Palaezoic, Mesozoic and Cenozoic Eras

From the close of the Precambrian Eras a long period of time has elapsed in which the various groups of sedimentary rocks underlying the surface of the south part of the Province were laid down in successive sea and fresh water lake basins. Some of these sediments may once have covered parts of the northern Precambrian area of the Province, but if so erosion has swept them away as no remnant of these rocks is known to occur well within this terrain.

Probably the northern area was, during the post-Precambrian Eras, one of generally low relief. It nevertheless during these times suffered further deep erosion and was the main source for the thousands of feet of material composing the sediments laid down in the southern part of the province, during the Palaezoic, Mesozoic, and Cenozoic Eras.

Igneous activity was more than once active within these eras in British Columbia but no igneous material of these ages intruded the rocks of Saskatchewan and the mountain building movements which culminated in the elevation of the mountain chains of British Columbia had but the slightest dislocating effect on the rocks of the Province.

The events that occurred in the Pleistocene, the epoc prior to the epoc in which we live, are of far reaching importance both from a geological and economic point of view. During this interval of time, due probably to a slight drop in the yearly mean temperature or an increase in the precipitation or both, the winter's accumulation of snow was not completely melted during the summers. The consolidation of this snow to ice, due to its own weight, resulted in great ice sheets accumulating over Northern Canada. Part of the Territories of Yukon and Alaska were not covered by these ice sheets due probably to a low precipitation. Owing to their great thickness and weight they flowed towards their margins and in doing so scoured and transported material from the surface of the country. The average thickness of material so removed could not be more than a few tens of feet in thickness and included the soil cover, unconsolidated river and lake deposits, and the upper few feet of the fresh bed rock as well. The present drainagesystems and lakes in the Precambrian areas of Canada are largely due to the gouging action of this ice, and damming, by the deposition of material at other points. The fresh bed rock outcrops in the north are

polished almost smooth and scratches on their surface, caused by the ice, show clearly the southerly movement of the ice and accounts for the veneer of glacial debris, containing Precambrian boulders, found over the surface of the prairies of the south of the Province. Very obviously the ice did most of its erosive work in the north and due to melting conditions deposited most of this material in the southern part of the region it once covered. These deposits being from a few to over a hundred feet in thickness.

There is considerable evidence in various parts of Canada and the northern States that there was more than one period of glaciation and that the last ice sheet retreated from northern Canada and northern Europe less than 20,000 years ago. The Greenland ice cap is a surviving remnant of the once extensive ice sheets.

Since the disappearance of these ice sheets the surface of the northern part of the Province has suffered little change. The fact, among others, that many lakes, even large ones like Wollaston, drain through two rivers clearly shows that sufficient time has not elapsed for a more normal state of affairs to be inaugurated by the ordinary processes of erosion working since the retreat of the Pleistocene ice. Peat material in muskegs and shallow lakes, river deltas, and some river flood plains are the relatively small amounts of material accumulated by the forces of erosion and deposition during this short Recent epoc.

SOME PROSPECTING CONSIDERATIONS

The nature and origin of metal mineral deposits has been the object of much study, as the finding and exploitation of such material is obviously of great interest and economic importance. The following sections merely touch on this highly complicated subject on which volumes have been written.

It has long been recognized that certain metal mineral deposits are associated and linked in their origin with certain rock types and other geological phenomena. This has naturally aided the search for such deposits, particularly as the metals of economic interest form, in all but a few cases, an exceedingly small proportion of the earth's crust. For instance, it has been estimated that lead, tin and zinc each form only a few hundred-thousandths of one per cent of the weight of the upper ten miles of the earth's crust, copper some hundred-thousandths or millionths of one percent, silver a tenth or a hundredth as much as copper, and gold one tenth as much as silver. Infinitesimal as these proportions seem, the various metal minerals are widely disseminated in the rocks. The processes of the formation of valuable mineral deposits are therefore, above all, processes of concentration by which the scattered valuable materials are brought together in relatively large quantities.

It has been proved beyond a doubt that the ultimate sources of the metal minerals are the igneous rock masses,- rocks that have crystallized from molten rock materials. By far the greatest quantity of these have cooled very slowly at depths within the earth's crust and are known as the plutonic igneous rocks. It has been found that all igneous rock types have a direct genetic relation to one another and it is very evident their differences are due to definite physical and chemical laws. It is known that, neglecting a few exceptions, there is an insensible gradation throughout the following common plutonic rock types; peridotites, gabbros, diorites, syenites and granites. The mineral groups forming all but a very small percentage of these rocks are only six in number and are olivines, pyroxenes, hornblendes, micas, plagioclase feldspars, orthoclase feldspar and quartz. The first mentioned minerals and rocks are dark in colour and the last mentioned light in colour. All these rock types are more or less equigranular, the grain averaging from 1/8 to 1/4 of an inch in diameter. Peridotites are largely composed of olivine (which often alters to the green mineral serpentine), gabbros contain the white to grey plagioclases and the dark or black pyroxenes, while diorites

contain the same feldspar but the black hornblendes instead of pyroxenes. Syenites and granites both contain the white or pink orthoclase feldspar, either micas or hornblende and granites in addition contain the glassy colourless mineral quartz.

In rocks like peridotites and gabbros in which the dark minerals olivines and pyroxenes form a large proportion of the mass, very small amounts of such minerals as ilmenite (titanium rich iron oxide), chromite (chromium rich iron oxide), phyrrhotite (iron sulphide), probably sulphides of iron, nickel and copper, and very rarely disseminated platinum minerals have also crystallized out of the molten rock mass. Large irregular segregations rich in such minerals as ilmenite and chromite are in places associated with large masses, many square miles in surface extent, of peridotites, gabbros and related rock types. Occasionally concentrations of nickeliferous phyrrhotite and sulphides of iron, nickel and copper are also present with such rocks.

Quartz diorites or grano-diorites, syenites and granites on consolidation result in the concentration in the remaining liquor of their more volatile constituents, the alkalies, quartz, water of deep-seated origin, the sulphides of the metals and many other valueless and valuable materials found in mineral deposits. At this stage dykes and relatively small bodies of pegmatite aplite and porphyry are apparently formed.

Pegmatite dykes are therefore rocks consolidated from liquids usually high in quartz, the alkalies and many rarer substances. They are light in colour and quite coarse in texture. Sometimes individual mineral crystals found in these rocks, like orthoclase feldspar are many inches in length. This is due to the presence of the rarer substances such as water and alkalies which lower the viscosity of these molten rocks, allowing great molecular mobility and opportunity of individual crystals growing by the addition of material from a comparatively long distance around. The chief minerals of value obtained from these coarse grained rocks are feldspar, quartz, micas, apatite, rare earths, molybdenite (molybdenum sulphide) cassiderite (tin oxide), pitchblende and some others. Often magnetite (the magnetic oxide of iron) is present in such rocks but is not to be expected in concentrations of value.

Aplites are believed to be similar in origin to the pegmatites but owing to the absence, at the time of consolidation, of the substances which lower viscosity, dykes of these rocks are found to be fine grained. In appearance they usually resemble a fine grained hornblende or mica poor granite or syenite. Many of the valuable mineralsnoted as occurring with the pegmatites are often found in small concentrations disseminated through them.

Porphyries occur in relatively small bodies a few thousands of feet across or in narrow linear masses, - dykes. Superficially they resemble granites and syenites, but on closer study are seen to be composed of relatively large mineral crystals 1/8 to 1/2 inch in diameter in a fine grained ground mass. Porphyries containing feldspar, an alkali rich mineral, as the large crystals are very often closely associated with veins and metal mineral sulphides and are believed to be the parent masses from which these final mineral concentrations are derived. It is for this reason that areas containing porphries are considered as favorable localities in which to prospect for metal mineral deposits.

The vein deposits which very often are rich in quartz are apparently an even richer concentration of the rarer substances of the original magma and they often are found at considerable distances from their parent source, usually in the sediments, volcanics and metamorphic schist equivalents of these rocks which have been intruded by and cover the plutonic rock masses. Owing to the chemically active nature of their constituents, their various pressures and temperatures of consolidation and the various reactions between these constituents and the country rocks they invade, they show a great variety of forms, textures and mineral content. Some of these

veins merely fill open fissures, others are formed largely by the replacement of the country rock they invade. Many important deposits of such valuable substances as gold, silver, copper, zinc, lead, cobalt, nickel, iron pyrites, tin, arsenic and many others have this origin.

Deposits of somewhat similar origin, but whose shape is not strictly vein-like, are the replacement deposits. These are often found in zones. These zones are composed of rocks, which, due to shattering or shearing, are more favourable for the passage of mineral solutions than are the adjacent more massive rocks, and which owing to this physical characteristic are more easily attacked and replaced; or these zones may be composed of rocks which like limestones or rhyolites are more susceptible to replacement by certain types of solutions than are adjacent sandstones or andesites. Many of the valuable sulphide deposits carrying one or more of the following metals, copper, zinc, lead, gold and silver, have this origin.

The tectonic or structural control of ore deposition is a very important factor. Under the folds developed in the earth's crust during its periods of mountain building have been more or less localized the large intrusive molten rock masses that are the original source of many ore deposits. The smaller features within these folds such as tilted and folded strata, resultant fractures and shear zones have, in many cases, been the loci for vein and replacement deposits. Later movements sometimes produce faulting and displacement of previously formed deposits, complicating their form and exploitation.

In any mineral deposit the important control may be one or more of the major geological processes. The resulting deposit will be simple or complex according to the nature, number and intensity of the processes involved.

The final chapter is the effect of erosion and weathering on the already complex resultant of earlier geological processes. The present earth's surface truncates many irregular structures, varied rock types and mineral deposits; areas that were at one time mountainous are now plains, the present surface cutting across the very roots of these former mountain chains, and areas that are now rugged were once featureless plains.

As has been previously pointed out the Precambrian rocks in Northern Saskatchewan are deeply eroded. The plutonic rock masses which consolidated deep within the earth's crust in this region and are the parent sources of the last mentioned valuable volatile constituents have been exposed over wide areas, and in many localities the present surface truncates these masses at great depths. In these areas practically all the deposits of value that once existed have been swept away. It is only in the areas where deep folding has aided in the preservation of relatively large masses of volcanics, sediments and their schist equivalents, the cover rocks of these once molten plutonic rock masses, that deposits of value are to be reasonably expected.

Naturally surface rocks that have not been intruded by molten rock material cannot contain veins or other mineral deposits related to plutonic igneous processes.

It seems certain that there is more than one age of granitic rocks in Northern Saskatchewan. It might therefore be expected that a later intrusive might have precipitated its valuable volatile constituents in the previously consolidated rock masses. Unfortunately plutonic rocks are similar in physical and chemical properties over very wide areas and the chances of localizing the rare and valuable emanations is therefore greatly lessened. Experience in many parts of the world has shown that the great regions of granitic rocks are singularly barren of valuable metal mineral deposits and it may be largely because of the above reasons.

As has previously been stated a recent event in the history of the earth's surface was the advance and retreat of vast sheets of ice over large areas of the earth. These sheets scoured the surface and scattered over it great quantities of debris which bears little or no resemblance to the underlying surface. As a result there are large areas of mineral bearing country, for instance sections of Northern Saskatchewan, where the rock exposures are few and prospecting is therefore much hampered.

Because the Yukon and Alaska were not invaded by the Pleistocene ice sheets rich placer gold deposits, concentrated through long previous periods of erosion, were not disturbed. Similar wealth probably existed in some of the pre-glacial river deposits of Northern Saskatchewan, but these band-like concentrations of value have been scattered broadcast over the prairies as ice has no tendency to sort material. Since the glacial epoc the rivers have resorted some of this debris and gold has again been concentrated. It has been pointed out, by F. H. Edmunds that the soil surveys of the Province show, that although the larger boulders on the prairies have travelled far from their source, the finer material with those boulders has not travelled as far and directly reflects the nature of the sub-glacial morain material. It therefore seems logical to expect that the rivers that have actively sorted the glacial morain nearest to the ancient placer sites will tend to have more gold in their bars than those further away. The rivers to the immediate south of the Precambrian area therefore promise more than those further south. Nevertheless rich placers are not to be expected in Saskatchewan.

A small amount of surface weathering has, of course, taken place since the disappearance of the Pleistocene ice sheets and as every prospector knows the iron bearing sulphide deposits are capped by a rusty gossan. Such prominent surface discolorations are always worth investigating as the unaltered material a few inches or feet below may contain minerals of economic importance. Gold does not weather or leach out of such zones and the panning of the gossan often shows the presence or absence of this valuable material in the underlying deposit.

The valuable deposits known in other Precambrian areas of Canada are localized in a few relatively small scattered districts, but the wealth already derived from those areas is great and promises much more. Even one small locality within Saskatchewan may yield much mineral wealth and there is reason to believe that there is more than one potentially valuable area within the Precambrian region of the Province. It must nevertheless also be borne in mind that in Canada there are on the average a thousand metal mineral claims, with showings of little or no value, to every claim which turns into a producing mine.